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APPLICATION FOR PATENT

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A.V. MAPA L.T.D. **א.ו. מפה בע"מ ח.פ. 513094052**
Gdod Evry 10 Ashqelon 78109 **רח' הגדוד העברי 10 אשקלון 78109**
Shlyakhetsky Victor **המממציאים - שלחצקי ויקטור ת.ז. 303411722**

Mostovoy Alexander **מוסטובוי אלכסנדר ת.ז. 306955386**

Tsvika Moalem **מועלם צביקה ת.ז. 022439384**

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(בעברית) **שיטה ומכשיר לבקרת הספק יציאה של מנוע AC**
(Hebrew)

(באנגלית)
A METHOD AND A DEVICE FOR CONTROLLING OUTPUT POWER OF AN AC MOTOR (English)

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A Method and a Device for Controlling Output Power of an AC Motor

Inventors:
Victor Shlyakhetsky, Alexander Mostovoy,
Tsvika Moalem

Applicant:
A.V. MAPA, Ltd.

ABSTRACT

A method of controlling output power of an AC motor realized by transforming power line AC voltage into unipolar, gapless sequence of pulses in the form of half waves of sinusoidal voltage, and by applying these voltage pulses, through a special device, in groups of one, two, or more pulses to the motor, while alternating direction of propagation of the pulses inside the motor. At the same time, each of the half waves is divided into a predetermined number of high frequency pulses. Number of pulses inside each half wave is adjusted to equalize amplitudes of current generated by each half wave and to keep them equal to a predetermined value. In the periods between pulses, energy flows are directed to pass through the engine, but not through the power source.

During starting of the motor, frequency and duty factor of the pulses are changed so that at the initial moment frequency and duty factor of the pulses are set to their maximal and minimal values, correspondingly. As the motor accelerates, frequency of the pulses is decreased, and width of the pulses is increased. During braking of the motor, the process goes into reverse direction.

The invention relates to the field electrical technology, and specifically the field of transformation of electrical energy into mechanical one. The proposed method could

be used to optimize operation of air conditioners, electrical fans, washing machines, electrical pumps, and other electrical appliances.

Background of the Invention

There is a known method of controlling output power of electrical motors by rectifying the power line's AC voltage and then transforming this voltage into rectangular pulses of variable width and direction. Width and frequency of the pulses, the period after which their polarity is reversed are changed to assure generation in the motor of quasi-sinusoidal current, with a given frequency and amplitude. The period of polarity reversal determines rotational speed of the motor, while amplitude of current in the engine determines the torque it generates. The main drawback of using this method for controlling power output of a motor is its low efficiency. The low efficiency is due to the following: generally, magnetic field is generated not only by current, but also by changing electric field (voltage), such as sinusoidally changing voltage of the AC power line, while, since in the described method the motor is fed by rectangular pulses that practically have no alternating component, here magnetic field is generated exclusively by current. Current, as is well known, generates heat, which leads to reduction in efficiency. Moreover, the quasi-sinusoidal current created in the motor leads to discrepancy between the shape of the power line voltage and the shape of current drawn from the power line, which results in violation of standing standards for electrical utilities customers. Methods and devices to which the above refers are described, for example, in the following patents.

1. Variable speed controller with improved efficiency of energy transfer for an AC induction motor. Patent USA 4,366,429 by inventor Robert D. Jackson.

2. Control method and apparatus for insufficient input voltage in an AC drive. Patent USA 6,313,600 B1 by inventors Peter W. Hammond *et al.*

Summary of the Invention

A method of controlling output power of an AC motor that reduces energy losses incurred in the process of control of rotational speed of the motor and of the torque it generates, and that also significantly reduces electrical disturbances generated in the power line by the motor and by the controlling device.

This goal is realized by transforming power line AC voltage into unipolar, gapless sequence of pulses in the form of half waves of sinusoidal voltage, and by applying these voltage pulses, through a special device, in groups of one, two, or more pulses to the motor, while alternating direction of propagation of the pulses inside the motor. At the same time, each of the half waves is divided into a predetermined number of high frequency pulses. Number of pulses inside each half wave is adjusted to equalize maximal amplitudes of current generated by each half wave and to keep them equal to a predetermined value. Additionally, the method provides for circular flow of induction currents inside the motor, which significantly reduces passing of electromagnetic disturbances to the power line.

The device that realizes the method comprises the device 1 for transforming sinusoidal voltage into unipolar half waves, the comparator 2 that signals beginning and end of the positive half period of sinusoidal voltage, the comparator 3 that signals beginning and end of the negative half period of sinusoidal voltage, the narrow pulses former 4, the frequency divider 5, the controller 6, the generator of high frequency pulses 7, the generator of high frequency pulses 8, the pulses summator 9, the pulses summator 10, the pulses summator 12, the switching device 13, the switching device 14, the switching device 15, the switching device 16, the switch 17, the switch 18, the switch 19, the switch 20, the electrical motor 22, the transformer 21, the diodes 23, 24, 25, 26. Inputs of the transforming device 1 are connected to the power line, and its outputs are connected inputs of the switches 17, 18, 19, 20. Outputs of the switches 17 and 20 are connected to one of lead wires of the motor 21, while outputs of the switches 18 and 19 are connected to another lead wire of the motor. Controlling inputs of the switches 17, 18, 19, 20 are connected to outputs of the switching devices 13, 14, 15, 16 driven by the controller, while inputs of the switching devices are connected as follows:

- inputs of the switching device 13 are connected to outputs of the summators 9 and 12;

- **inputs of the switching device 15 are connected to output of the summators 10 and to inverting output of the summators 12;**
- **inputs of the switching device 14 are connected to output of the frequency divider 5 and to output of the comparator 3;**
- **inputs of the switching device 16 are connected to output of the frequency divider 5 and to output of the comparator 2.**

Controlling inputs of the switching devices are connected to outputs of the controller 6.

Inputs of the summator 9 are connected to outputs of the comparator 2 and the generator 7, while inputs of the summator 10 are connected to outputs of the comparator 3 and the generator 8. Output of the comparator 3 is also connected, through the narrow pulses former 4, with input of the frequency divider.

Controlling inputs of the generators 7 and 8 are connected to outputs of the controller. The diodes 23 – 26 are connected in parallel to the switches 17 – 20.

Brief Description of the Drawings

Figure 1. Illustrated the process of transforming 50 Hz AC sinusoidal voltage into 25 Hz AC voltage.

Figure 2. Illustrated the process of transforming 50 Hz AC sinusoidal voltage into 16.6 Hz AC voltage.

Figure 3. Shows width of pulses inside of each half wave during transformation of 50 Hz AC voltage into 25 Hz AC voltage.

Figure 4. Block diagram of the power control system.

Figure 5. Time diagrams of voltages generated during operation of the system.

Description of the Preferred Embodiment

The device operates as follows. The power line AC voltage is rectified by the transforming device 1 realized, for example, as a full wave rectifier built using high speed diodes, and is transmitted, as unipolar half waves of sinusoidal voltage, to inputs of the switches. When switches 17 and 20 are closed, the half waves are passing through the motor, without distortions, providing that the period during which the switches stay open is a multiple of a half period of the AC voltage. When switches 17 and 20 are closed, the switches 18 and 19 are open. When the switches 18 and 19 are closed for the period that is a multiple of a half period of the AC voltage, while the switches 17 and 20 are opened, the voltage half waves pass through the motor in the reverse direction. A time diagram of voltage applied to the motor, in the case when the period of the switches staying closed is 2 times half period of the AC voltage, is shown in the Fig.1. The switching period, this is the period during which the switches stay either open or closed, is determined with help of the comparators 2 and 3. (See Fig.4.) The comparators generate rectangular pulses whose width is approximately equal to a half period of the AC voltage. (See Fig.5.) If the switching period is equal to a half period of the AC voltage, signals from the comparators are applied directly to controlling inputs of the switches 19 and 20, through the switching devices 15 and 16. The signals from the comparators that are applied to controlling inputs of the switches 19 and 20 are combined with pulses from the high frequency pulses generator by the mixers (summators) 9 and 10. Opening and closing of the switches 18 or 17 divides each half wave into high frequency pulses, whose number is determined by frequency of the generator. At the same time, since the switch 20 remains closed during the half wave period, while the switch 17 operates in the pulse mode, when the switch 17 is opened, current accumulated in the motor flows in the closed circuit, through the switch 19 and the diode 26. The pair of switches 18, 19 operates similarly. In the case when the switches are driven by signals from the comparator that have passed through the frequency divider 5 (see Fig.4), the switching period is a multiple of a half wave period of the AC voltage. (See Fig.2.) Practically, this means that, since the ratio of the switching period to the period of the AC voltage is equal to the number of the unipolar half wave sinusoidal pulses in the group, rotational speed of the motor decreases proportionally to this number. Decrease in the rotational speed of the motor leads to increase of current in the motor's windings, because, at constant feeding voltage, amount of electrical energy consumed by the motor remains the same, regardless of

the rotational speed, while at the lower speed it cannot be fully transformed into mechanical energy. Varying number and width of pulses inside each half wave is used as the means of controlling amount of electrical energy consumed by the motor. At the same time, as experiments have shown, inside a group, current is increasing with each successive half wave, which is due to increase in residual magnetization of the motor's core. To compensate for this effect, variable width of pulses inside a half wave is used. (See Fig.3.)

Claims

1. A method of controlling output power of an AC motor, a single phase motor for example, by changing frequency of the feeding voltage, such that the power line AC voltage is transformed into unipolar sequence of pulses in the form of half waves of sinusoidal voltage, and by applying these voltage pulses, through a special device, in groups of one, two, or more pulses to the motor, while alternating direction of propagation of the group of pulses inside the motor, and while each of the half waves is divided into a set number of high frequency pulses.

2. A method as claimed in 1, such that, for each group, half waves of AC voltage in the same group are divided into a number of pulses that varies depending on the position of the half wave inside the group, for example: width of the pulses in the second half wave is 1.5 – 2 times narrower than in the first half wave, and width of the pulses in the third half wave is 1.5 times narrower than in the second half wave.

3. A method as claimed in 2, such that the motor's current is measured, during each half wave of sinusoidal voltage, and width of pulses inside each half wave is so adjusted that maximal currents during each half wave are equalized and kept equal to a preset value.
4. A method as claimed in 1, such that, in between high frequency pulses, energy flows circulate within the motor and the motor control system.

5. A method as claimed in 1, such that numbers of half waves within groups of different polarity do not coincide.

6. A method as claimed in 1, such that time interval during which the high frequency pulses are formed is limited to a certain zone inside each half wave.

7. A method as claimed in 6, such that width of the high frequency pulses at the beginning of each half wave is greater than their width at the end of the half wave.

8. A method as claimed in 1, such that, in the group of unipolar half waves, each half wave is followed by a narrow demagnetizing pulse of opposite polarity.

9. A method as claimed in 7, such that the parameter of the motor's operation, *cos φ*, is continuously measured, and the width of pulses in the last half wave of the group is appropriately decreased, so that, when the group of half waves changes polarity, current in the motor is equal to zero.

10. A method as claimed in 1, such that, during operation of the motor, shape of the motor's current is compared with a standard sinusoidal curve, and width of the high frequency pulses is adjusted to assure maximal congruency of the current with the sinusoidal curve; for example, if amplitude of the current exceeds the required amplitude, then width of the pulses is increased, and if amplitude of the current is less than the required amplitude, then width of the pulses is decreased, while taking into account time delay of the control signals in relation to the current amplitude of the current.

11. A method as claimed in 1, such that rotational speed of the engine is continuously measured and the number of half waves in the group is changed to maintain the required rotational speed; for example, if the speed exceeds the required value, the number of half waves in each group, both positive and negative, is increased, and, if the speed falls below the required value, the number of half waves is decreased, in the groups of one and the same polarity.

12. A method as claimed in 1, such that, at the starting of a motor, each half wave is divided into the maximal possible number of pulses, each of the minimal width, and then frequency of the pulses is gradually decreased, and their width increased, until they reach the prescribed values.

13. A device for controlling output power of an AC motor comprising a diode bridge, a transistor bridge, a controller, and electronic switches, such that it also contains he comparator 2 that signals beginning and end of the positive half period of sinusoidal voltage, the comparator 3 that signals beginning and end of the negative half period of sinusoidal voltage, the narrow pulses former 4, the frequency divider 5, the controller 6, the generator of high frequency pulses 7, the generator of high frequency pulses 8, the pulses summator 9, the pulses summator 10, the pulses summator 12, the switching device 13, the switching device 14, the switching device 15, the switching device 16, the switch 17, the switch 18, the switch 19, the switch 20, the transformer 21, the diodes 23, 24, 25, 26,

where

controlling inputs of the switches 17, 18, 19, 20 are connected to outputs of the switching devices 13, 14, 15 , 16 driven by the controller, while inputs of the switching devices are connected as follows:

- inputs of the switching device 13 are connected to outputs of the summators 9 and 12;
- inputs of the switching device 15 are connected to output of the summators 10 and to inverting output of the summators 12;
- inputs of the switching device 14 are connected to output of the frequency divider 5 and to output of the comparator 3;
- inputs of the switching device 16 are connected to output of the frequency divider 5 and to output of the comparator 2;

and where controlling inputs of the switching devices are connected to outputs of the controller 6; inputs of the summator 9 are connected to outputs of the comparator 2 and the generator 7, while inputs of the summator 10 are connected to outputs of the comparator 3 and the generator 8; output of the comparator 3 is also connected, through the narrow pulses former 4, with input

of the frequency divider; controlling inputs of the generators 7 and 8 are connected to outputs of the controller.

14. A device as claimed in 13, such that it also contain a current sensor that monitors the motor's current, while output of the sensor is connected with an input of the controller.

15. A device as claimed in 13, such that it also contain a rotational speed sensor that monitors the motor's speed , while output of the sensor is connected with an input of the controller.

Victor Shlyakhetsky, Alexander Mostovoy,
Tsvika Moalem

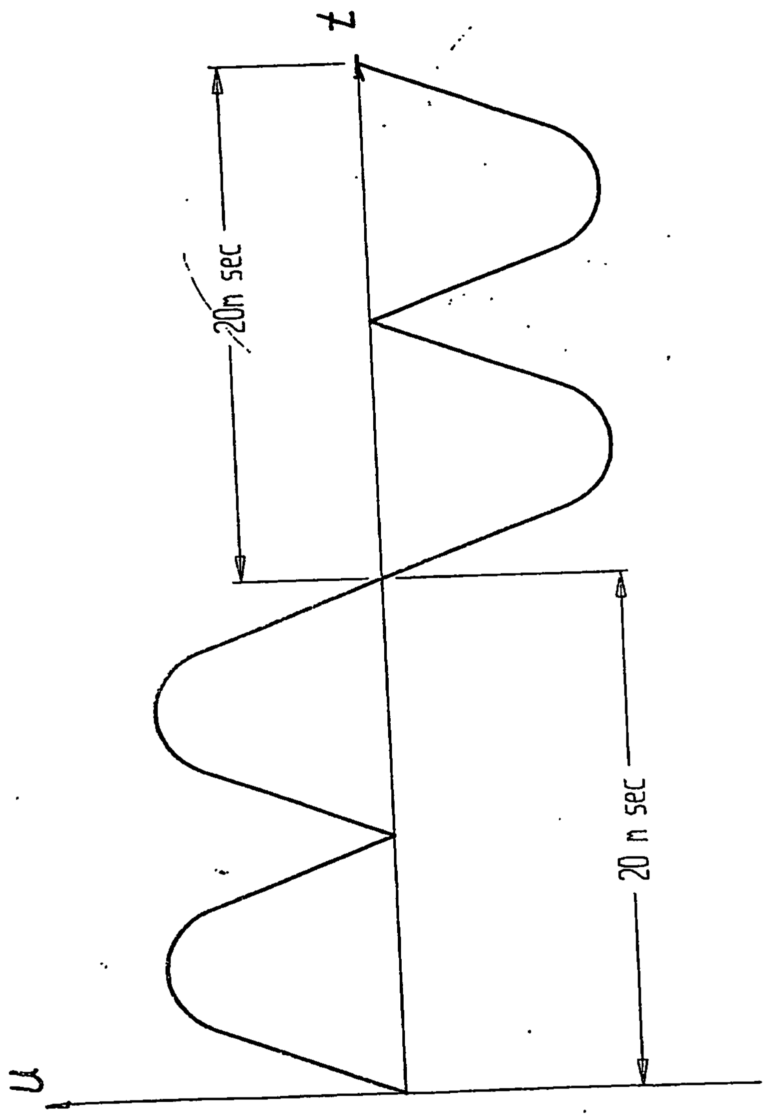

Fig 1

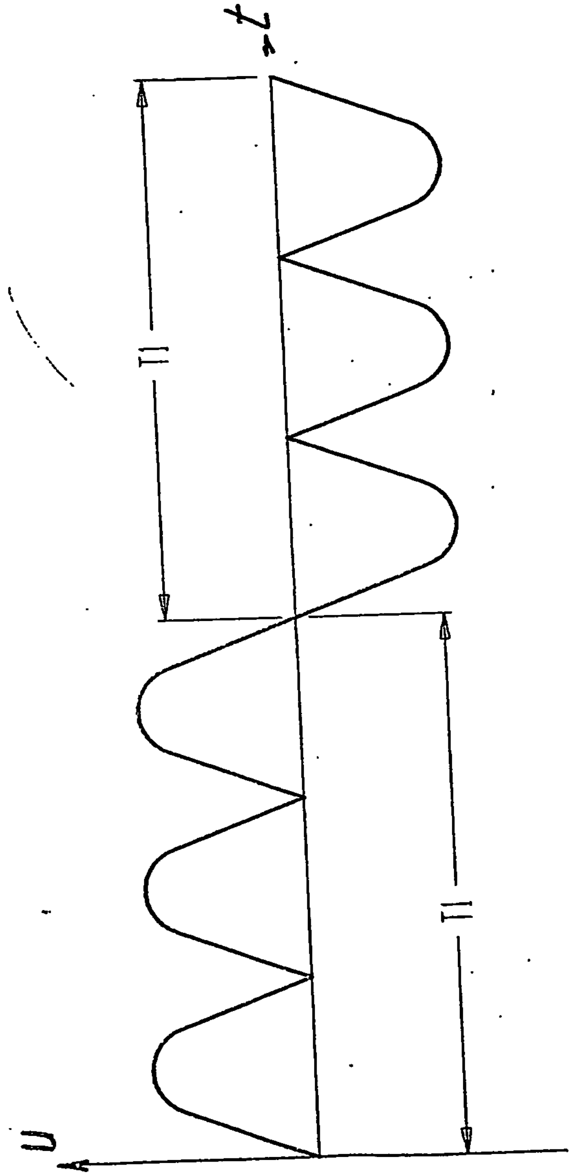

Fig 2

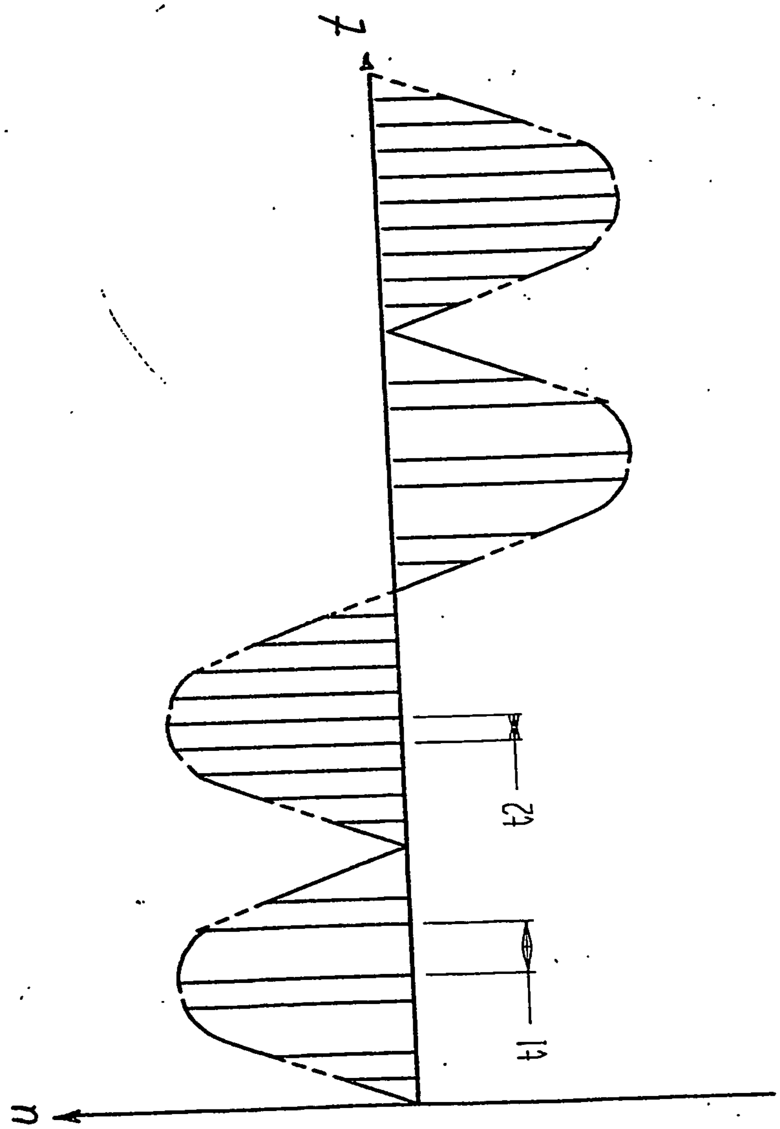

Fig 3

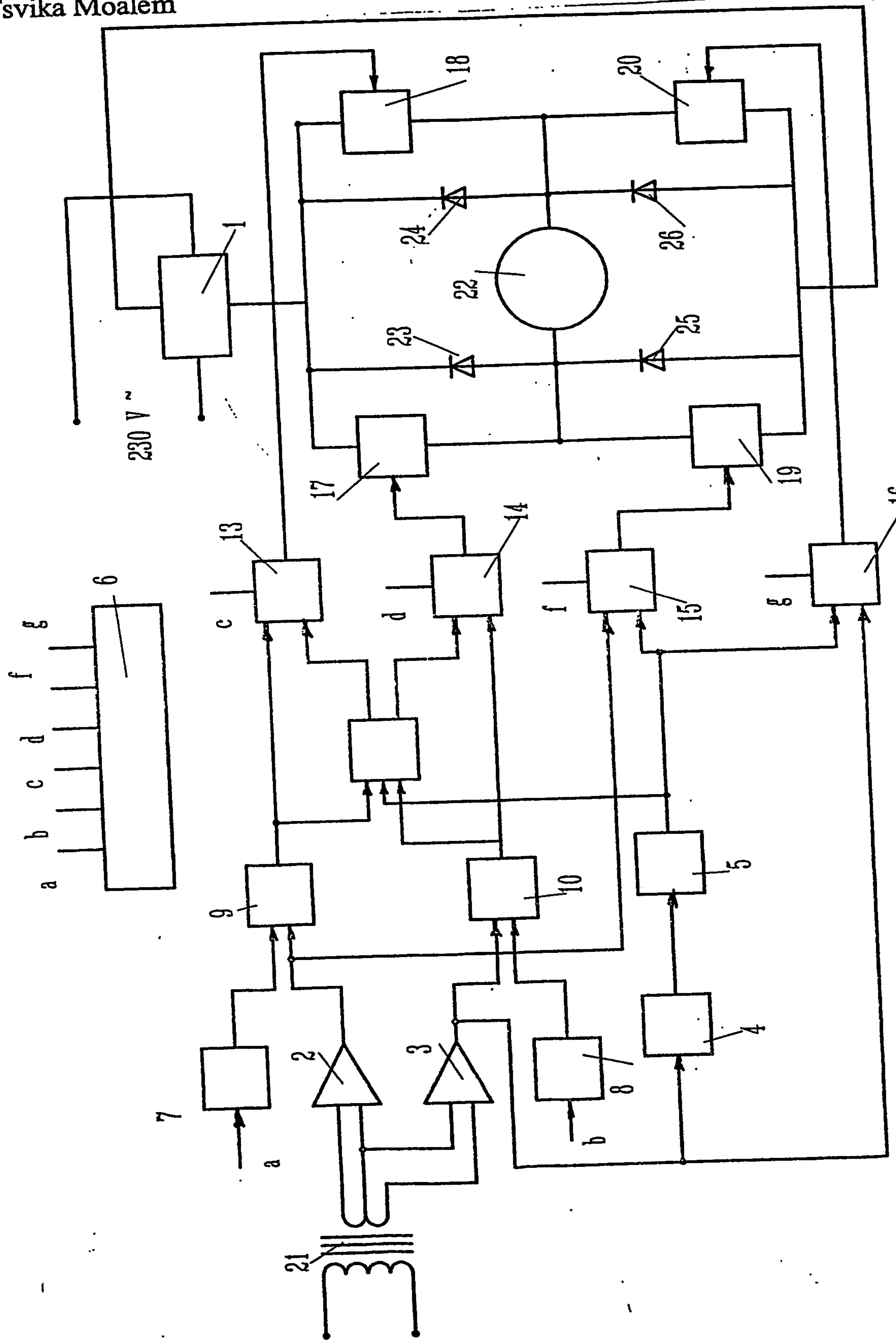

Fig 4

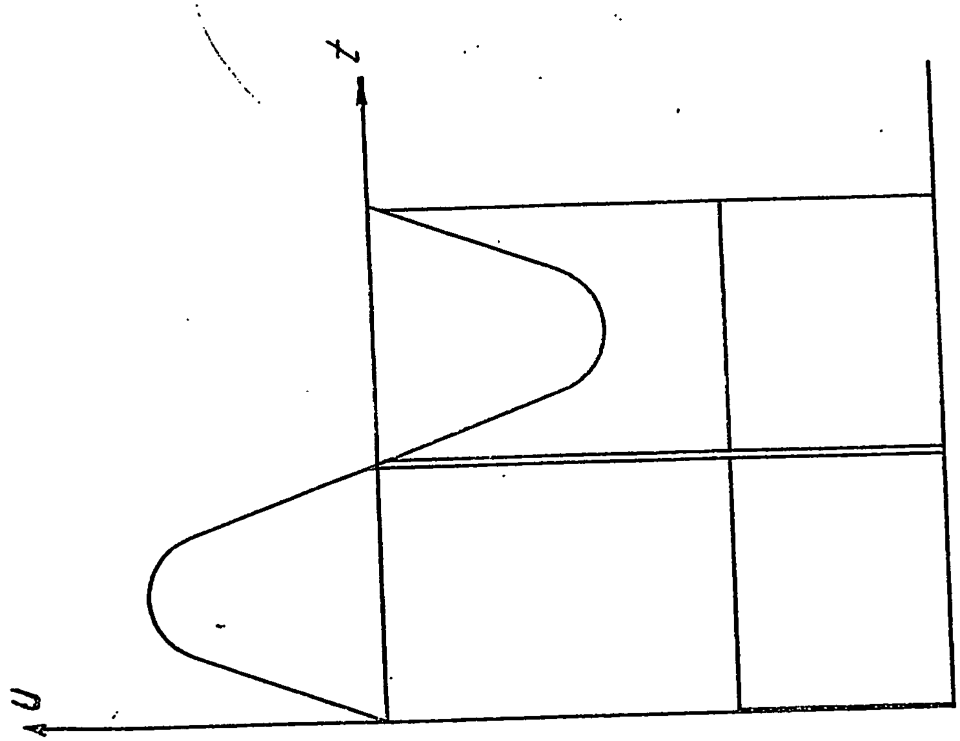

Fig 5

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